

Predicting Rainfall Erosivity in Honduras

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1 **PREDICTING RAINFALL EROSIVITY IN HONDURAS**

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16

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PREDICTING RAINFALL EROSIVITY IN HONDURAS

ABSTRACT

The rainfall erosivity index (R) from the Universal Soil Loss Equation (USLE) (Wischmeier and Smith, 1965; 1978) and its modern version, the Revised Universal Soil Loss Equation (RUSLE) (Renard et al., 1991; Renard et al., 1994), was utilized to evaluate rainfall erosivity in Honduras. In addition to average annual precipitation, elevation was highly significant in predicting the rainfall erosivity. Analyses of data sets from Costa Rica, Sri Lanka, and the southeastern United States showed similar patterns. Using previously calculated R-factor values for eight climatic stations in Honduras, a regression relationship was established for estimating the rainfall erosivity index as a function of average annual precipitation and elevation. This regression model was used to estimate the rainfall erosivity index for each of the 352 Honduran climatic stations without calculated R-factor values. A provisional iso-erodent map of Honduras at a scale 1:1,000,000 was compiled, using a basemap obtained from the Digital Chart of the World (Environmental Systems Research Institute, Inc, 1993). The iso-erodent map displays ranges of the R-factor values and iso-lines

1 representing 95% prediction intervals for new R-factor
2 estimates.

3

4 INTRODUCTION

5

6 Climatic erosivity is defined (Lal, 1990) as the
7 aggressiveness of the climate (rain, wind, snow) toward
8 erosion. The rainfall erosivity factor (R), or R-factor,
9 in the USLE/RUSLE model (Wischmeier and Smith, 1965, 1978;
10 Renard et al., 1994) is an index of rainfall erosivity,
11 which allows prediction of the potential erosive power of
12 the rainfall. The methods used to calculate the R-factor
13 are described by Wischmeier and Smith (1978) and in the
14 RUSLE user guide (Renard et al., 1994).

15 The rainfall erosivity factor was the focus of this
16 study because it can provide useful information independent
17 of the USLE/RUSLE model. Iso-erodent maps produced on the
18 basis of this factor can be used to identify regions with
19 high rainfall erosive potential. The R-factor values can
20 be readily calculated for locations where hourly rainfall
21 intensities are known (Wischmeier and Smith, 1978).
22 However, calculation of the R-factor values for new
23 locations is laborious and requires long-term rainfall
24 intensity data. Such information for Honduras was limited.
25 Alternatively, rainfall erosivity has been estimated from
26 average annual precipitation data (Renard and Freimund,

1 1994). Bollinne et al. (1980) developed a provisional iso-
2 erodent map for Belgium; precipitation was utilized to
3 estimate R by simple linear regression using three
4 observations. An iso-erodent map of India (Babu et al.,
5 1978) was based on average annual and seasonal
6 precipitation for 44 climatic stations.

7 The objectives of the study reported here were to
8 collect from numerous sources the basic climatic data for
9 weather stations in Honduras, to use this information to
10 estimate R-factor values, and to produce an iso-erodent map
11 for the country. The estimation of R-factor values is
12 based on the use of both elevation and average annual
13 precipitation as regressors. This procedure improves
14 substantially over the use of precipitation data only,
15 which is the approach of previous work on this topic.

16

17 **MATERIALS AND METHODS**

18

19 Previously existing calculated erosivity indices for
20 eight climatic stations in the El Cajón watershed and the
21 mean annual precipitation and elevation of these stations
22 are presented in Table 1. Each erosivity index is an
23 average value over a 15 to 16 year period. The rainfall
24 energy per unit depth of rainfall (e_r), a component used in
25 calculating the R-factor value, was estimated using the
26 relation (Foster et al., 1981)

$$\begin{aligned}
 & e_r = 0.119 + 0.0873 \log_{10}(i_r) & i_r \leq 76 \text{ mm h}^{-1} \\
 & e_r = 0.283 & i_r > 76 \text{ mm h}^{-1} \quad (1)
 \end{aligned}$$

where

e_r = kinetic energy in megajoules per hectare per millimeter of rainfall ($\text{MJ ha}^{-1} \text{ mm}^{-1}$);
 i_r = intensity of rainfall (mm h^{-1}).

A modification of the general procedure for developing a rainfall erosivity map as discussed by Renard and Freimund (1994) was used in this study; it is outlined in the following steps:

- 1) Calculated R-factor values for climatic stations were obtained wherever possible from existing studies;
- 2) A linear regression relationship was developed between the calculated R-factor values and the average annual precipitation and elevation values for these climatic stations;
- 3) The developed relationship was used to estimate R-factor values for other climatic stations without calculated R-factor values;
- 4) Estimated and calculated R-factor values were plotted on a map, and iso-lines (iso-

1 erodents) were drawn connecting points with equal
2 R-factor values. Space between iso-erodents was
3 coded according to the range of the predicted
4 R-factor values. R-factor values for sites
5 between iso-erodents may be predicted by linear
6 interpolation.

7
8 The climatic data used in this study were obtained
9 from various sources: articles, theses, and climatic
10 reports as well as Honduran institutions, such as Empresa
11 Nacional de Energía Eléctrica (ENEE), Departamento de
12 Servicios Hidrológicos y Climatológicos de Honduras (DSHC),
13 Servicio Meteorológico Nacional de Honduras (SMN), Servicio
14 Nacional de Acueductos y Alcantarillas (SANAA), and many
15 other agencies and institutions (see Mikhailova, 1995a,b
16 for a complete compilation of climatic data and a reference
17 list of data sources).

18 The basemap of Honduras used in this study is a
19 1:1,000,000-scale vector basemap obtained from the Digital
20 Chart of the World, a comprehensive geographic information
21 system (GIS) database for use with ARC/INFO® and ArcView®
22 software (Environmental Systems Research Institute, Inc.,
23 1993).

24 The regression approach for estimating R-factor values
25 was used in conjunction with a GIS to compile the iso-
26 erodent map of Honduras. The Universal Soil Loss Equation

1 (USLE) and the Revised Universal Soil Loss Equation (RUSLE)
 2 have been interfaced with geographic information systems in
 3 earlier studies (Spanner et al., 1982; Blaszczyński, 1992).
 4

5 RESULTS AND DISCUSSION

7 Predicting Rainfall Erosivity from Average Annual 8 Precipitation and Elevation

10 Inspection and statistical analysis of the data in
 11 Table 1 showed a positive linear relationship between
 12 rainfall erosivity index and average annual precipitation,
 13 and a negative linear relationship between rainfall
 14 erosivity and elevation (Fig. 1, Fig. 2, respectively).
 15

16 A linear regression relationship was established
 17 estimating the rainfall erosivity index (R) from the
 18 average annual precipitation and elevation:

$$19 \quad R_i = -699.3 + 7.0001 P_i - 2.7190 E_i \quad (2)$$

20
 21 where i denotes location $i = 1, 2, 3 \dots n$, at which

22 R_i = point estimate of R-factor value;

23 P_i = average annual precipitation in mm;

24 E_i = elevation in meters.
 25

1 The coefficient of multiple determination (R^2) for
2 this regression equation is 0.972 ($p = 0.000$). Elevation
3 was statistically significant, with a partial t -value of
4 -4.46 ($p = 0.007$). This data set did not have any
5 multicollinearity problems (Neter et al., 1990, p.295), as
6 indicated by the tolerance value of 0.959. Statistical
7 diagnostics did not reveal any deviations from the
8 assumptions of the multiple regression model.

9 To the authors' knowledge, elevation has not been
10 used previously for predicting the rainfall erosivity
11 index. Studies in Costa Rica and Sri Lanka (Vahrson, 1990;
12 Joshua, 1977) suggested an inverse relationship between
13 rainfall erosivity and elevation. To examine the
14 significance of elevation in estimating the rainfall
15 erosivity index for other geographic areas, published data
16 sets for Costa Rica (Vahrson, 1990; Instituto Meteorologico
17 Nacional de Costa Rica, 1988), Sri Lanka (Joshua, 1977;
18 Domroes and Ranatunge, 1993), and selected states from the
19 southeastern United States (CITY Database of RUSLE, Version
20 1.03, 1993) were analyzed statistically.

21 Table 2 presents the summary of predictive equations
22 for the R-factor values for Honduras, Costa Rica, Sri
23 Lanka, and the southeastern United States. In all four
24 cases there is an inverse relationship between rainfall
25 erosivity index (R) and elevation, and the coefficient of
26 multiple determination of each multiple regression model

1 increased significantly when elevation was incorporated as
2 a second predictor variable, after average annual
3 precipitation.

4 A possible explanation for the inverse relationship
5 between R-factor and elevation is as follows. R-factor is
6 calculated from the kinetic energy of individual
7 rainstorms. The kinetic energy of an individual storm is
8 dependent on rainfall intensity, which is influenced by the
9 median raindrop size and the terminal velocity of the free-
10 falling raindrops. The median raindrop size generally
11 increases with greater rain intensity (Wischmeier and
12 Smith, 1958) and the terminal velocities of free-falling
13 water-drops increase with larger drop size (Gunn and
14 Kinzer, 1949). According to Beard (1985), the altitude
15 factor for adjusting raindrop velocities from sea level
16 depends primarily on air density and drop size. Air
17 density decreases by about seven percent for every 1,000 m
18 (3,280 feet) of elevation, so the kinetic energy of falling
19 raindrops should be greater at 1,000 m elevation than at
20 sea level (McIsaac, 1990). Conversely, at greater heights
21 there are more small drops and very few large drops,
22 because of the absence of pronounced accretion (Caton,
23 1966). Also, there is less raindrop coalescence at higher
24 elevations because of decreased distance between the clouds
25 and the ground. Therefore at higher elevations, the low
26 concentration of large drops formed by accretion and

1 coalescence causes a decrease in raindrop mass, which could
2 overcome the influence of decreased air density on velocity
3 and consequently could result in a net decrease in the
4 kinetic energy. This suggested hypothesis has not been
5 investigated by field studies.

6

7 **Developing the Iso-erodent Map**

8

9 Climatic stations of Honduras were plotted on the
10 basemap of Honduras (Fig. 3, data layer 1) according to
11 their geographic coordinates. To create the average annual
12 precipitation data layer of Honduras (Fig. 3, data layer
13 2), an inverse distance weighted (IDW) interpolation
14 routine within the GIS (ARC/INFO®, version 6.1.2) was used
15 to interpolate between station points and assign an average
16 annual precipitation value to each 10 by 10 km grid-cell on
17 the map. The elevation data layer (Fig. 3, data layer 3)
18 was obtained from the Digital Chart of the World
19 (Environmental Systems Research Institute, Inc, 1993).
20 A data layer of the estimated R-factor value for each grid-
21 cell (Fig. 3, data layer 4) was generated using equation
22 (2) with inputs from the average annual precipitation data
23 layer and the elevation data layer.

24 A 95% prediction interval for the R-factor value at
25 every location can be found in GIS from the general
26 prediction interval formula (Neter et al., 1990, p.246).

1 The estimated variance matrix of the regression coefficient
 2 estimates is used to obtain the 95% prediction interval at
 3 each new location, given by

$$\begin{aligned}
 & \left[855014 - 935.847 P_i - 674.647 E_i + \right]^{1/2} \\
 5 \quad R_i \pm 2.571 & \left[\begin{array}{l} 0.390148 P_i^2 + 0.370995 E_i^2 + \\ 0.153343 P_i E_i \end{array} \right] \quad (3)
 \end{aligned}$$

6
 7 where i denotes location $i = 1, 2, 3 \dots n$, at which
 8 R_i = point estimate of R-factor value (equation (2));
 9 P_i = average annual precipitation in mm;
 10 E_i = elevation in meters.

11
 12 Expressing the R-factor point estimate and 95%
 13 prediction interval in this algebraic form allows the
 14 estimation of the R-factor value and corresponding 95%
 15 prediction interval for each 10 by 10 km grid-cell in the
 16 GIS interface. Using equation (3), separate data layers
 17 were generated containing the upper (Fig. 3, data layer 5)
 18 and lower (Fig. 3, data layer 6) prediction limits for the
 19 R-factor estimate for each grid-cell. The lower prediction
 20 limit values were then subtracted from the upper values to
 21 obtain a third data layer containing the 95% prediction
 22 interval width for the R-factor estimate for each grid-cell
 23 (Fig. 3, data layer 7). These values were used to produce
 24 contour lines representing the width of the 95% prediction
 25 interval of the new R-factor estimates (Fig. 3, data layer

1 8). These contour lines were then added to the iso-erodent
2 map of Honduras.

3

4 **Provisional Iso-erodent Map of Honduras**

5

6 The iso-erodent map of Honduras is presented in
7 Fig. 4. Different ranges of the estimated R-factor value
8 are coded by color. The new R-factor estimate can be
9 obtained from the map with its corresponding 95% prediction
10 interval. For example, the solid yellow region in southern
11 Honduras represents the range of the estimated R-factor
12 value from 8000 to 11999 MJ mm ha⁻¹ h⁻¹ y⁻¹, and the width
13 of the 95% prediction interval is 3000 MJ mm ha⁻¹ h⁻¹ y⁻¹;
14 therefore the 95% prediction interval for the R-factor
15 value is between 8000 ± 1500 and 11999 ± 1500 MJ mm ha⁻¹ h⁻¹
16 y⁻¹. For any location of interest, both a point estimate
17 and a prediction interval for the R-factor value can be
18 obtained from the digital provisional map of Honduras
19 (Mikhailova, 1995b).

20 The lowest range of estimated R-factor value, from 0
21 to 3999 MJ mm ha⁻¹ h⁻¹ y⁻¹, is found primarily near the
22 capital of Honduras, Tegucigalpa. Estimated R-factor
23 values for this central region of the country generally
24 vary from 0 to 8000 MJ mm ha⁻¹ h⁻¹ y⁻¹.

25 The high range of estimated R-factor values, from 8000
26 to 16000 MJ mm ha⁻¹ h⁻¹ y⁻¹, is found primarily in the

1 coastal regions, as well as in the Lake Yojoa area, which
2 is inland.

3 The Caribbean lowlands in northeastern Honduras are
4 characterized by the highest range of estimated R-factor
5 values, greater than 16000 MJ mm ha⁻¹ h⁻¹ y⁻¹. This region
6 also has the highest average annual precipitation (Perfil
7 Ambiental de Honduras, 1989).

8 The contour lines representing the width of the 95%
9 prediction interval for the R-factor value are shown in
10 Fig. 4 in increments of 1000 R-factor units on the
11 provisional iso-erodent map of Honduras. This approach
12 allows for the identification of areas where the multiple
13 regression model (2) used to predict R-factor values may
14 not be appropriate. The best estimates of the R-factor
15 values, with the narrowest prediction intervals, are found
16 near the eight climatic stations with calculated R-factor
17 values. Any station with average annual precipitation
18 outside the range of 831 to 1313 mm or elevation outside
19 the range of 360 to 1080 m has a wide prediction interval.
20 Wide prediction intervals are associated with R-factor
21 values for the stations in the Caribbean lowlands.

22

23 **Limitations of the Study**

24

25 The validity of using the rainfall erosivity index (R)
26 as a predictor of rainfall erosive power in Honduras has

1 not been verified by field studies. The expense of setting
 2 up and maintaining field equipment is one major reason why
 3 this has not been done in the framework of this study. The
 4 rainfall energy for the R-factor estimates (Zavgorodnaya de
 5 Costales, 1990) used in this study were calculated from
 6 equation (1), which is not the most current method for
 7 estimating rainfall energy. Equation (1) has recently been
 8 replaced by another relation (Brown and Foster, 1987):

$$9 \quad e_r = 0.29 [1 - 0.72 \exp(-0.05 i_r)] \quad (4)$$

11 where

12 e_r = kinetic energy in megajoules per hectare per
 13 millimeter of rainfall ($\text{MJ ha}^{-1} \text{ mm}^{-1}$);
 14 i_r = intensity of rainfall (mm h^{-1}).

16
 17 Equation (4) is a better estimator of rainfall energy
 18 than equation (1) because it is based on more data than the
 19 relationship in equation (1) (Brown and Foster, 1987).
 20 Even though equation (1) was used in Honduras to estimate
 21 rainfall energy, comparison of the two relations (equation
 22 (1) and equation (4)) in the United States resulted in a
 23 difference of less than 1% in the EI (storm erosivity
 24 index) of sample storms (Renard et al., 1994). It was
 25 impossible to recalculate the rainfall energy per unit
 26 depth of rainfall using equation (4) for the eight stations

1 used in this study, because the daily rainfall records were
2 not available. However, such recalculation could increase
3 the accuracy of this study.

4 R-factor values have been estimated from average
5 annual precipitation and elevation data obtained from many
6 different sources. Frequently, values of geographic
7 coordinates and elevation for the same station have varied
8 from one source to another. The most recent available
9 climatic data and geographic coordinates have been selected
10 for this study. If more accurate climatic information is
11 obtained in the future for any station, the estimated R-
12 factor value can be recalculated easily using equation (2).

13 The most accurate R-factor estimates are obtained for
14 the stations whose average annual precipitation and
15 elevation values fall in the joint region outlined by the
16 circle in Fig. 5. Because regression equation (2) is
17 obtained from observations all lying within this circle,
18 extrapolation is required for observations far outside this
19 circle. Therefore, regression equation (2) may not be
20 appropriate for estimating R-factor values for stations
21 whose average annual precipitation falls far outside the
22 range of 831 to 1313 mm or whose elevation falls far
23 outside the range of 360 to 1080 m. Most of the stations
24 located in the coastal areas of Honduras are outside of
25 these ranges of average annual precipitation and elevation.
26 Furthermore, the eight stations with calculated R-factor

1 values have similar monthly rainfall distributions (Fig.
2 6), so using equation (2) to estimate R-factor values may
3 not be appropriate for those stations with different
4 monthly rainfall distribution.

5 The eight stations with calculated R-factor values are
6 located in the El Cajón watershed area, which represents
7 approximately 8% of the national territory of Honduras
8 (Zavgorodnaya de Costales, 1990). Since the iso-erodent
9 map of Honduras is based on only these eight calculated R-
10 factor values, it should be viewed as a preliminary study
11 to evaluate rainfall erosivity. The small number of
12 stations with calculated R-factor values and the density of
13 climatic stations in Honduras did not allow the use of
14 spatial statistics, such as kriging, to determine the
15 accuracy of the estimated mean R-factor values in different
16 geographic areas of Honduras.

17 All statistical calculations in this study were
18 performed using the Minitab® statistical software program
19 (Ryan et al., 1994). It should be noted for further
20 investigations that use of different computer regression
21 packages may lead to slightly different numerical results,
22 because of the numerical accuracy of the calculations
23 (Neter et al., 1990, p.262). Finally, there is unknown
24 error introduced by the interpolation in the GIS routines
25 used to generate the various data layers and by the

1 overlaying of data layers with different spatial
2 resolutions.

3 The limitations in the prediction of the rainfall
4 erosivity in Honduras by the method of this study should
5 not be discouraging for people who must make decisions on
6 land use in the country. The iso-erodent map presented in
7 this study represents the best available information for
8 Honduras. As pointed out by Van Wambeke (1987),
9 information with known limitations can lead to better
10 decisions, if used carefully, than those made without
11 information.

REFERENCES

- 1
- 2
- 3 Babu, R., K.G. Tejawani, M.C. Agarwal and L.S. Bhushan.
- 4 1978. Distribution of erosion index and iso-erodent
- 5 map of India. Indian J. Soil Conserv. 6(1):1-12.
- 6 Beard, K.V. 1985. Simple altitude adjustments to raindrop
- 7 velocities for Doppler radar analysis. J. of
- 8 Atmospheric and Oceanic Technology 2:468-471.
- 9 Blaszczyński, J. 1992. Regional soil loss prediction
- 10 utilizing the RUSLE/GIS interface. p. 122-131. In A.I.
- 11 Johnson, C.B. Pettersson, and J.L. Fulton (ed.),
- 12 Geographic Information Systems (GIS) and Mapping -
- 13 Practices and Standards. ASTM STP 1126. American
- 14 Society for Testing and Materials, Philadelphia.
- 15 Bollinne, A., A. Laurant, P. Rosseau, J.M. Pauwels, D.
- 16 Gabriels and J. Aelterman. 1980. Provisional rain
- 17 erosivity map of Belgium. In M. DeBoodt and D.
- 18 Gabriels (ed.), Assessment of Erosion. John Wiley &
- 19 Sons, Chichester. p. 111-120.
- 20 Bonilla, R.M. 1991. Determinación de las tasas de erosión
- 21 para la cuenca El Cajon y priorización de áreas de
- 22 tratamiento (vol.II). Thesis. Universidad Nacional
- 23 Autónoma de Honduras, Facultad de Ingeniería.
- 24 Brown, L.C., and G.R. Foster. 1987. Storm erosivity using
- 25 idealized intensity distributions. Trans. ASAE 30:379-
- 26 386.

- 1 Caton, P.G.F. 1966. A study of raindrop-size distributions
2 in the free atmosphere. *Quat. J. Royal Meteor. Soc.*
3 92:15-30.
- 4 CITY Database of RUSLE, Version 1.03, 1993. Soil and Water
5 Conservation Society.
- 6 Domroes, M., and E. Ranatunge. 1993. A statistical approach
7 towards a regionalization of daily rainfall in Sri
8 Lanka. *International Journal of Climatology* 13:741-
9 754.
- 10 Environmental Systems Research Institute, Inc. 1993.
11 Digital chart of the world for use with ARC/INFO®
12 software.
- 13 Foster, G.R., D.K. McCool, K.G. Renard, and W.C.
14 Moldenhauer. 1981. Conversion of the Universal Soil
15 Loss Equation to SI metric units. *J. of Soil and Water*
16 *Conserv.* 36(6):355-359.
- 17 Gunn, R., and G.D. Kinzer. 1949. Terminal velocity of fall
18 for water droplets in stagnant air. *J. of Meteor.*
19 6(4):243-248.
- 20 Instituto Meteorológico Nacional de Costa Rica. 1988.
21 Catastro de las series de precipitaciones medidas en
22 Costa Rica. Ministerio de Recursos Naturales, Energía
23 y Minas. Costa Rica, San Jose.
- 24 Joshua, W.D. 1977. Soil erosive power of rainfall in the
25 different climatic zones of Sri Lanka. p 51-61. *In*
26 *Erosion and Solid Matter Transport in Inland Waters.*

- 1 IAHS-AISH Publication No. 122. Symposium, Paris, July
2 1977.
- 3 Lal, R. 1990. Soil Erosion in the Tropics: Principles and
4 Management. McGraw-Hill, New York.
- 5 McIsaac, G.F. 1990. Apparent geographic and atmospheric
6 influences on raindrop sizes and rainfall kinetic
7 energy. J. Soil Water Conserv. 45(6):663-666.
- 8 Mikhailova, E.A. 1995a. Predicting rainfall erosivity in
9 Honduras. M.S. thesis. Dept. of Soil, Crop and
10 Atmospheric Sciences, Cornell Univ., Ithaca, NY.
- 11 Mikhailova, E.A. 1995b. Predicting rainfall erosivity in
12 Honduras. Cornell International Institute for Food,
13 Agriculture and Development (CIIFAD). Box 14 Kennedy
14 Hall, Cornell University, Ithaca, NY 14853.
- 15 Neter, J., W. Wasserman, and M.H. Kutner. 1990. Applied
16 Linear Statistical Models: Regression, Analysis of
17 Variance, and Experimental Designs. 3rd ed. Richard
18 D.Irwin, Inc., Homewood, IL.
- 19 Perfil Ambiental de Honduras. 1989. Secretaría de
20 Planificación , Coordinación y Presupuesto (SECPLAN),
21 Development Strategies for Fragile Lands (DESFIL).
22 Funded by United States Agency for International
23 Development.
- 24 Renard, K.G., and J.R. Freimund. 1994. Using monthly
25 precipitation data to estimate the R-factor in the
26 revised USLE. Journal of Hydrology 157:287-306.

- 1 Renard, K.G., G.R. Foster, G.A. Weesies, and D.K. McCool,
2 (Coordinators). 1994. Predicting soil erosion by water
3 - a guide to conservation planning with the revised
4 universal soil loss equation (RUSLE). Agriculture
5 Handbook 703. US Govt. Printing Office, in press.
- 6 Renard, K.G., G.R. Foster, G.A. Weesies, and J.P. Porter.
7 1991. RUSLE - revised universal soil loss equation. J.
8 Soil Water Conserv. 46(1):30-33.
- 9 Ryan, B.F. and B.L. Joiner. 1994. Minitab Handbook. 3rd ed.
10 Duxbury Press, An Imprint of Wadsworth Publishing
11 Company, Belmont, CA.
- 12 Spanner, M.A., A.H. Strahler, and J.E. Estes. 1982. Soil
13 loss prediction in a Geographic Information System
14 format. In Papers Selected for Presentation at the
15 Sixteenth International Symposium on Remote Sensing of
16 Environment. Vol. 1. 2-9 June 1982. Buenos Aires,
17 Argentina.
- 18 Vahrson, W. 1990. El potencial erosivo de la lluvia en
19 Costa Rica. Agronomía Costarricense 14(1):15-24.
- 20 Van Wambeke, A. 1987. Soil moisture and temperature regimes
21 of Central America, Caribbean, and Mexico. SMSS
22 Technical Monograph # 16, Soil Conservation Service,
23 U.S.D.A., Washington, D.C.
- 24 Wischmeier, W.H., and D.D. Smith. 1958. Rainfall energy and
25 its relationship to soil loss. Trans. AGU 39:285-291.

- 1 Wischmeier, W.H. and D.D. Smith. 1978. Predicting rainfall
2 erosion losses - a guide to conservation planning.
3 Agriculture Handbook No. 537, USDA, Washington.
- 4 Wischmeier, W.H. and D.D. Smith. 1965. Predicting rainfall-
5 erosion losses from cropland east of the Rocky
6 Mountains - guide for selection of practices for soil
7 and water conservation. Agriculture Handbook No. 282.
8 USDA, Washington, DC.
- 9 Zavgorodnaya de Costales, S. 1990. Trabajos Geomorfológicos
10 Cuantitativos en la Cuenca El Cajón. Empresa Nacional
11 de Energía Eléctrica, Tegucigalpa, Honduras.

TABLE CAPTIONS

1

2

3 Table 1. Calculated erosivity index R for selected
4 climatic stations in the El Cajón watershed area
5 (Zavgorodnaya de Costales, 1990; Bonilla, 1991).

6 Table 2. Summary of predictive equations for Honduras,
7 Costa Rica, Sri Lanka, and Southeastern USA.

Table 1. Calculated erosivity index R for selected climatic stations in the El Cajón watershed area (Zavgorodnaya de Costales, 1990; Bonilla, 1991).

Station	Latitude			Longitude			Mean annual	Elevation	R-factor
	North			West			rainfall		SI units
	°	'	"	°	'	"	mm	m	MJ mm ha ⁻¹ h ⁻¹ y ⁻¹
PLAYITAS	14	25	25	87	42	06	890	595	4035†
LA ERMITA	14	28	00	87	04	05	928	760	3934‡
VICTORIA	14	56	07	87	23	22	1313	360	7297†
SANTA CLARA	14	26	38	87	17	00	1272	740	6114†
AGUA CALIENTE	14	40	39	87	17	25	1261	560	6995‡
FLORES	14	17	30	87	34	06	831	620	2980†
EL COYOLAR	14	19	00	87	30	39	862	800	3385‡

(continued)

SIGUATEPEQUE	14	34	53	87	50	25	1154	1080	4248†
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† Average of 15 years.

‡ Average of 16 years.

Table 2. Summary of predictive equations for
Honduras, Costa Rica, Sri Lanka, and
Southeastern USA.

Equation	<i>n</i>	<i>df</i> [†]	<i>MSE</i>	<i>R</i> ^{2‡}	<i>p</i> -value
<u>Honduras</u>					
$R = -3172.0 + 7.5620 P$	8	6	460371	0.860	0.001
$R = 7696.0 - 4.0950 E$	8	6	2411857	0.265	0.192
$R = -699.3 + 7.0001 P - 2.7190 E$	8	5	110808	0.972	0.000
<u>Costa Rica</u>					
$R = 2110.1 + 1.4743 P$	111	109	6841829	0.330	0.000
$R = 8449.9 - 1.8263 E$	111	109	7729583	0.243	0.000
$R = 3786.6 + 1.5679 P - 1.9809 E$	111	108	3979794	0.614	0.000
<u>Sri Lanka</u>					
$R = -727.0 + 3.7711 P$	8	6	2081153	0.857	0.001
$R = 6063.0 - 3.9850 E$	8	6	13602653	0.067	0.535
$R = -344.1 + 3.8473 P - 4.8460 E$	8	5	764276	0.956	0.000

(continued)

Southeastern USA

$R = -9100.0 + 11.8500 P$	24	22	3346952	0.497	0.000
$R = 6891.0 - 2.8793 E$	24	22	4457593	0.330	0.003
$R = -5704.0 + 9.7580 P - 1.9475 E$	24	21	2562077	0.632	0.000

† Degrees of freedom (*df*) associated with Mean Square Error (*MSE*).

‡ Coefficient of (multiple) determination.

R R-factor estimate in SI units: MJ mm ha⁻¹ h⁻¹ y⁻¹.

P Average annual precipitation in mm.

E Elevation in meters.

FIGURE CAPTIONS

- 1
- 2
- 3 Fig. 1. The relationship between calculated R-factor (R)
- 4 and average annual precipitation (P) at eight
- 5 climatic stations in Honduras.
- 6 Fig. 2. The relationship between calculated R-factor (R)
- 7 and elevation (E) at eight climatic stations in
- 8 Honduras.
- 9 Fig. 3. Schematic representation of the approach used to
- 10 produce provisional iso-erodent map of Honduras.
- 11 Fig. 4. Provisional iso-erodent map of Honduras (modified
- 12 from Mikhailova, 1995a,b).
- 13 Fig. 5. Plot of elevation against average annual
- 14 precipitation for stations with calculated
- 15 and estimated R-factor values.
- 16 Fig. 6. Average monthly rainfall distribution for eight
- 17 stations with calculated R-factor values.

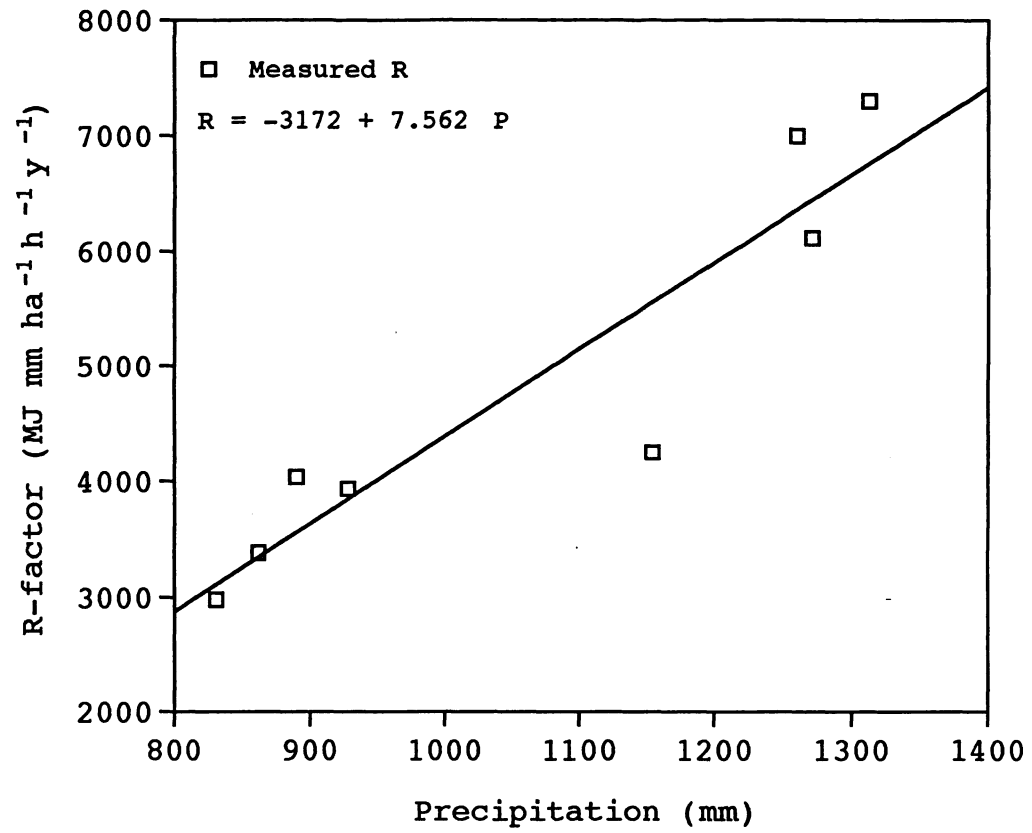


Fig. 1

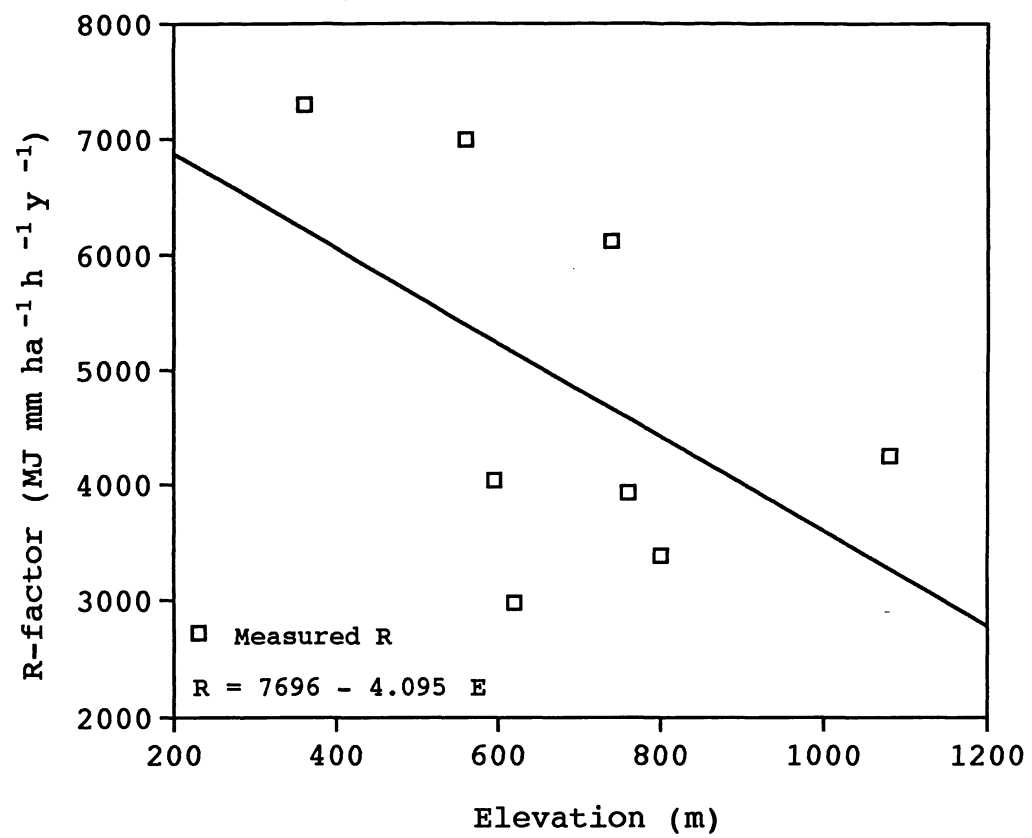


Fig. 2

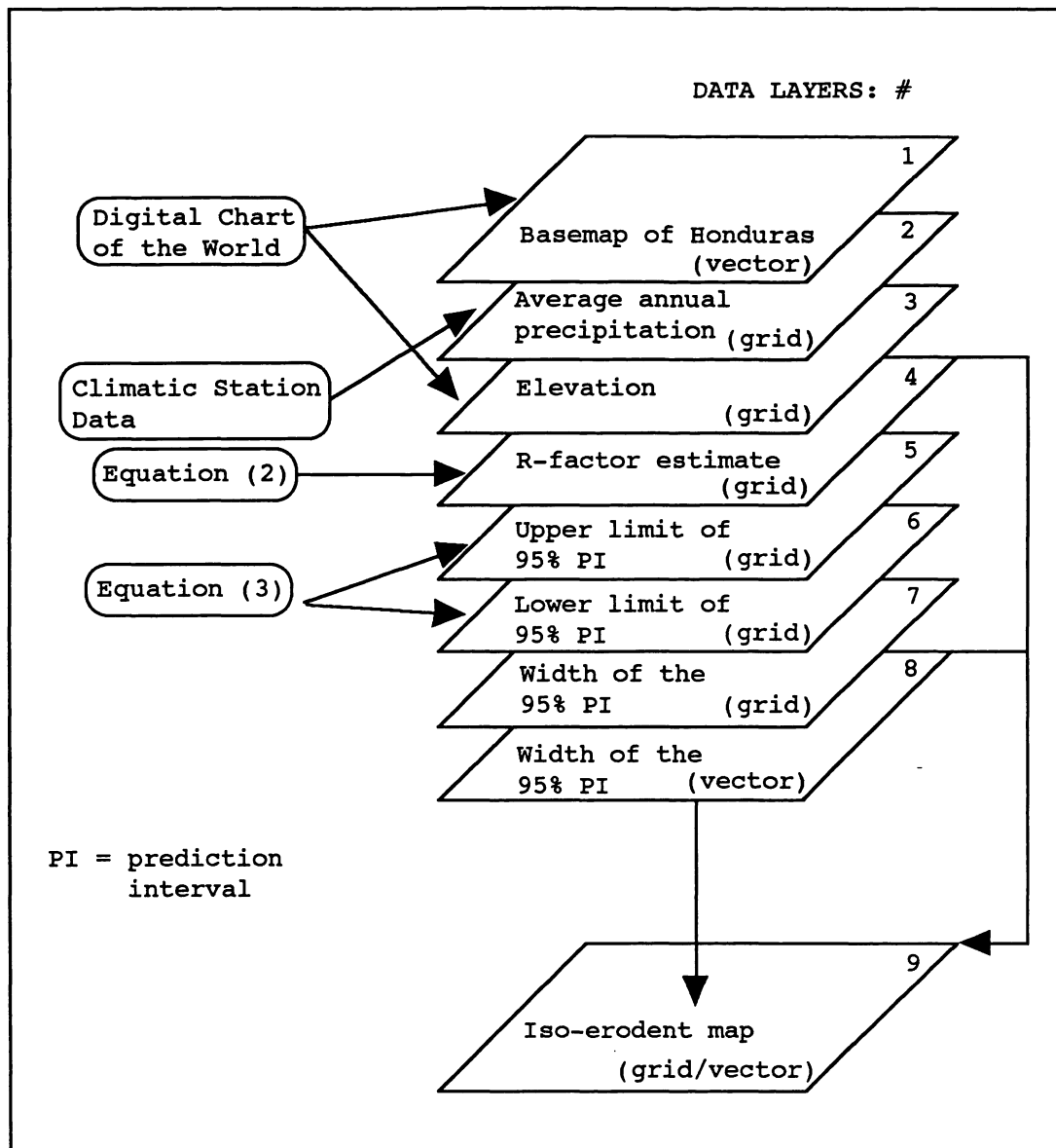


Fig. 3

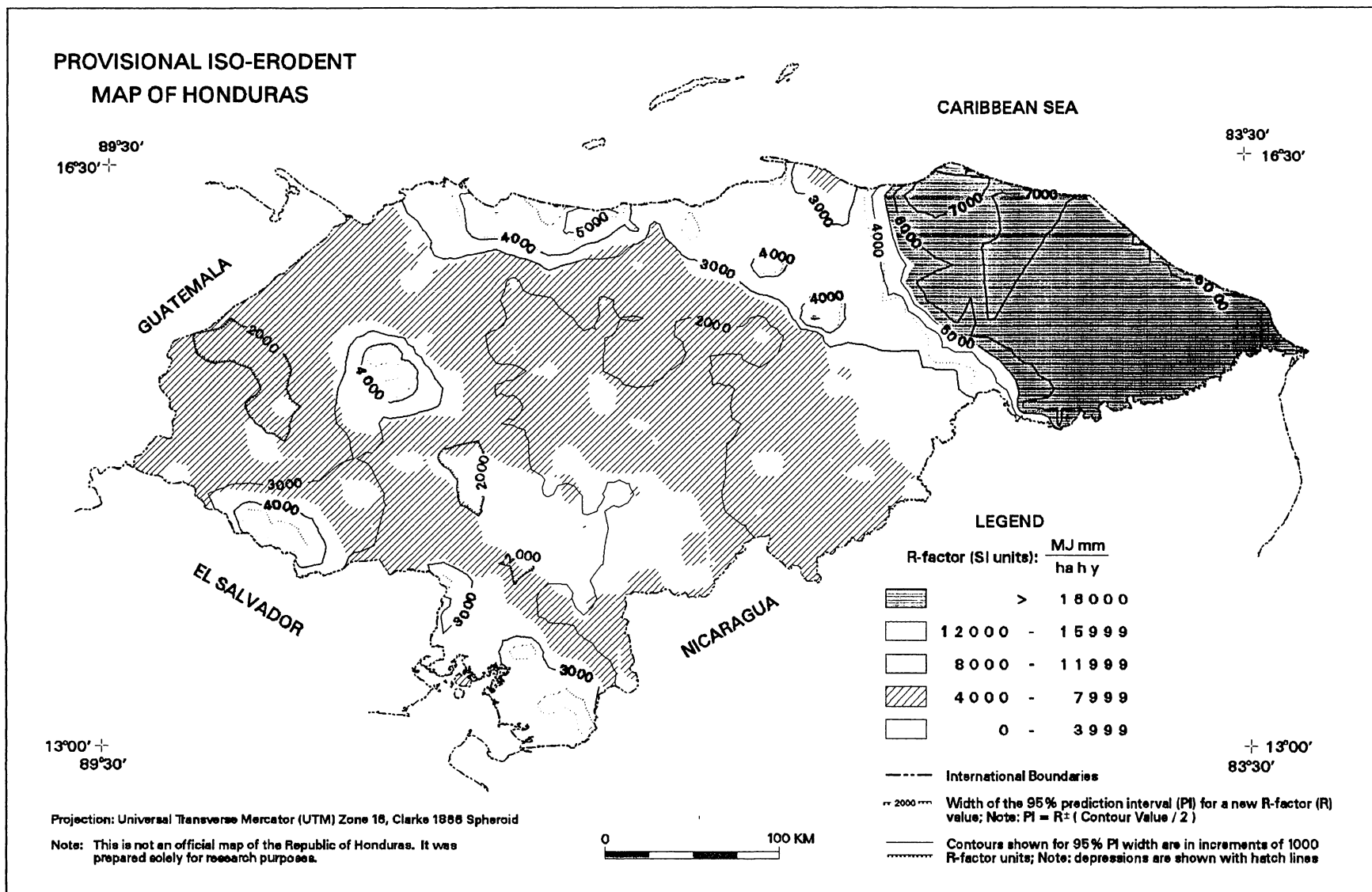


Fig. 4

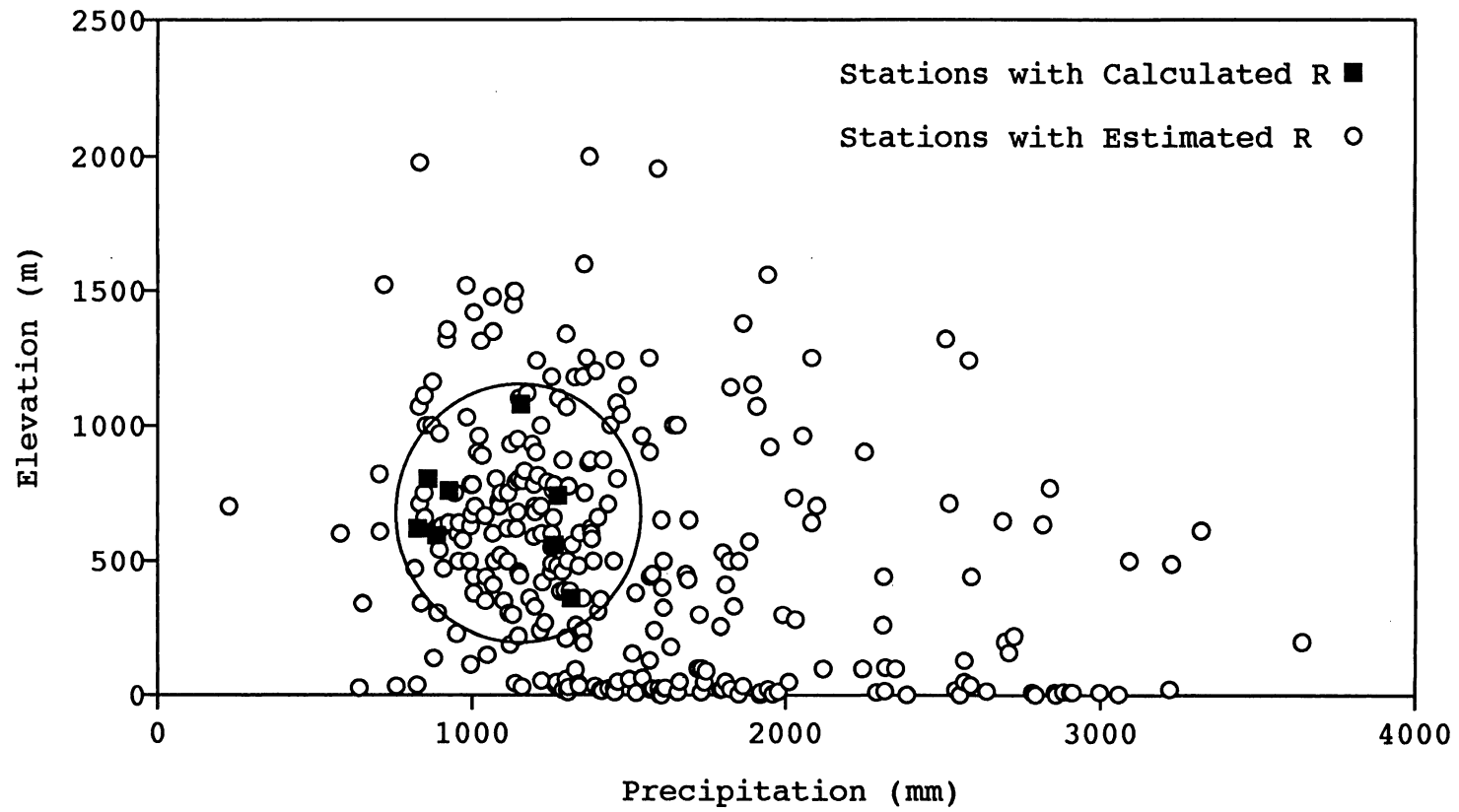


Fig. 5

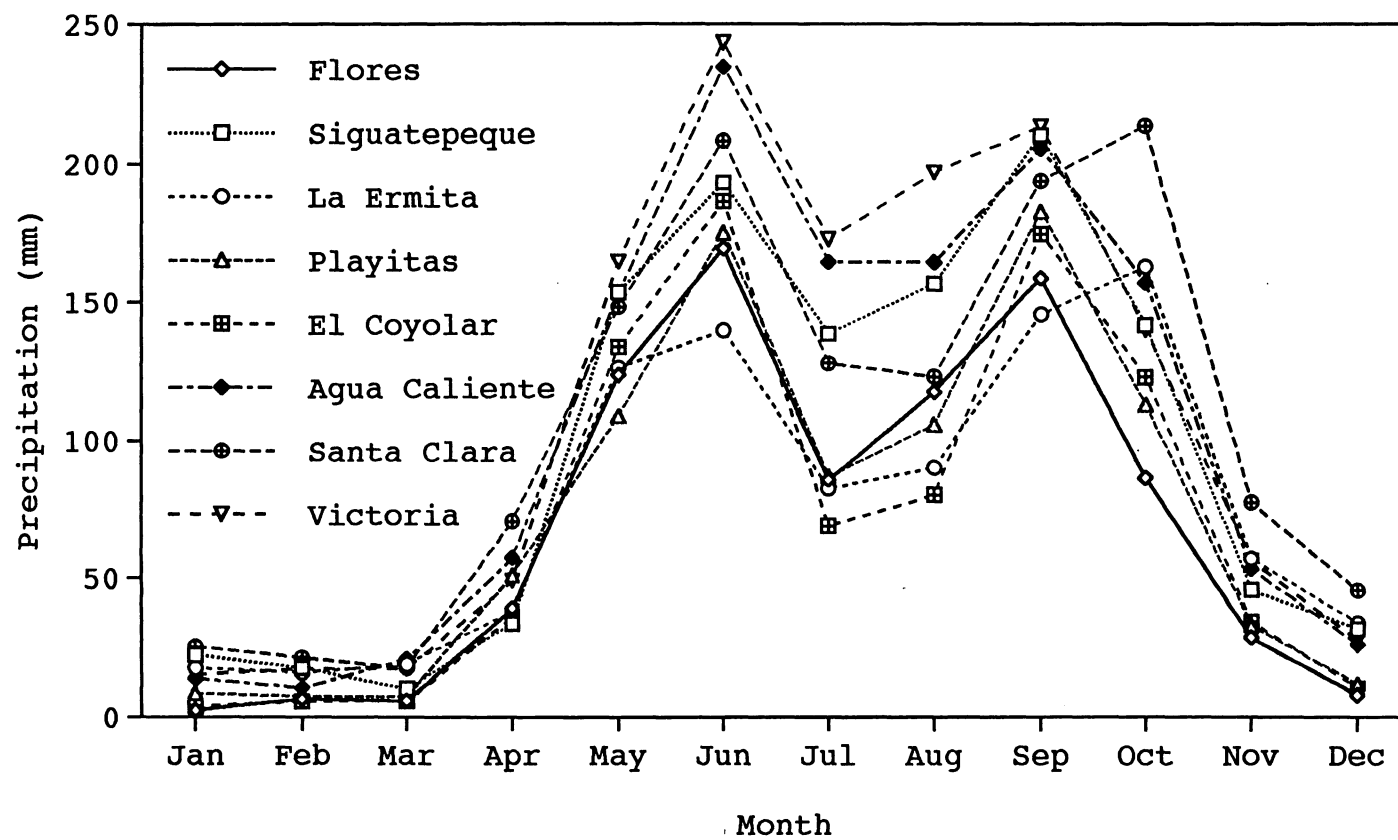


Fig. 6